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Comparative Assessment of Softness and Cohesiveness Indices, Colour Characteristics and Consumers' Acceptability of Doughmeals from Yam, Plantain and Whole Wheat

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Abstract

This study investigated the production of doughmeals from three different botanical sources with the aim of evaluating their comparative quality characteristics and acceptability. Flours were prepared individually from yam (*Dioscorea rotundata*), plantain (M*usa aab*) and whole wheat (T*riticum aestivum* L.); and reconstituted to prepare doughmeal respectively. There were significant variations ($p<0.05$) in physicochemical properties of the flours such as mean particle size (120-136 µm) and the pasting characteristics. The pasting properties of the flours used for doughmeal preparation were significantly different ($p<0.05$) in peak, final and setback viscosities. The softness index of doughmeal prepared from the flours of yam, plantain and whole wheat were 21.8, 25.3 and 27 mm respectively while there were significant variations ($p<0.05$) in the compression test characteristics of doughmeal prepared from the different botanical sources. The brown index (colour descriptive factor) of doughmeal prepared from the flours of yam, plantain and whole wheat were 45.8, 46.3 and 42.2 respectively. The sensory quality rating of doughmeal from yam was rated the highest in virtually all the sensory factors including colour, taste, texture (mouldability) and overall acceptability. The objective variables and sensory evaluation have therefore shown that consumers still have cultural affinity and greater preference for the traditional food product (yam doughmeal) than those from other sources.

Keywords: Doughmeal, a*mala*, flour, yam, plantain, whole wheat, quality

1. Introduction

Yam doughmeal (*amala*) is a traditional thick paste consumed in West African countries such as Benin, Togo, Ghana, Côte d'Ivoire and Nigeria (Akissoe *et al*., 2006). This traditional food product is commonly prepared through a combination of yam (*Dioscorea rotundata*) flour, water and thermal energy to form a gel-like food product. It is one of the most important yam-based traditional food products among the Yoruba ethnic group in southwestern Nigeria apart from pounded yam. Yam doughmeal is essentially a carbohydrate food but still contains other nutrients in small quantitities. Tubers from *Dioscorea rotundata* cultivars, particularly from *kokoro* group, are generally used for the preparation of yam flour meant for doughmeal production (Chilaka *et al*., 2002) and this is because the tubers are believed to give the best doughmeal. However, it has been reported that dried Florido tubers (*Dioscorea alata*) and Nigerian improved water yam (*Dioscorea alata*) genotypes can similarly give doughmeal of similar quality as the one produced from *kokoro* tubers (Vernier *et al*., 1999; Ukpabi *et al*., 2008). The quality factors usually used by the consumers in determining the acceptability of yam doughmeal include the texture (elasticity and non-stickiness), colour (brownish) and taste (Chilaka *et al*., 2002; Akissoe *et al*., 2001). The ultimate consumption of yam doughmeal is usually with any of the local vegetable soups and stews (e.g. *ewedu, gbegiri, ila, orula, abula*, *efo,* etc.) as a side dish with or without meat and this normally serves as a source of additional nutrients such as protein, minerals and vitamins.

In Nigeria as well as other yam-dough-meal-consuming West African countries (Benin, Togo, Ghana and Côte d'Ivoire), flours from other botanical sources such as plantain (*Musa AAB*) and cassava (*Manihot esculenta*) are similarly used to prepare doughmeal while the use of whole wheat (*Triticum aestivum* L.) flour is a more recent development. The various botanical sources from which doughmeal can be prepared fundamentally have diverse chemical compositions (Ihekoronye and Ngoddy, 1985; Okwu and Ndu, 2006) and therefore have a high tendency of conferring different properties on the respective doughmeals obtained from them thereby giving rise to food products of diverse quality characteristics.

Therefore, in view of the fact that many consumers now go for doughmeal from yam, plantain or wheat, there is the need to carry out a comparative assessment of the quality characteristics of these doughmeals and their general acceptability. This assessment will be of great relevance in an event of commercialization of the doughmeal production.

2. Materials and Methods

2.1 Sources of materials

The yam tubers (D*ioscorea rotundata*) and green matured plantain (*Musa AAB*) were obtained from a farmer's farm at Ilara-Mokin, Ondo State, Nigeria; while whole wheat grains (*Triticum spp.*) used for this study were purchased from Bodija market, Ibadan, Oyo State, Nigeria.

2.2 Production of flour from yam tubers, green matured plantain and whole wheat grains

Production of flour from yam tubers: Flour was produced from yam tubers in the laboratory following the method described by Ige and Akintunde (1981) with some modifications. The yam tubers were thoroughly washed with portable water to remove adhering soil and other undesirable materials. Peeling was carried out manually with a sharp knife and the peeled yam tubers were sliced into 2 cm thickness so as to quicken the process of drying. The yam slices were parboiled in a thermostat-controlled water bath set at 65^{o}C for 20 min and then left to cool in the parboiling water for 12 h in order to become flabby, after which they were drained and dried at 60°C for 72 h in a cabinet dryer (model NBDR, Grieve, USA). The dried yam slices were crushed in a locally fabricated hammer mill, milled into flour in a locally fabricated plate mill and then allowed to cool. The flour obtained was finally sieved using a sieve of 300-µm aperture and then packaged in black polyethylene bag until needed for further analysis.

Production of flour from plantain: Flour was similarly obtained from green matured plantain by washing the fingers followed by peeling, slicing (1-cm thick) and drying in the cabinet dryer at 60°C for 36 h. The dried plantain slices were then crushed in a locally fabricated hammer mill, milled into flour in a locally fabricated plate mill and then allowed to cool. The flour obtained was finally sieved using a sieve of 300-µm aperture and then kept in black polyethylene bag until needed for subsequent analysis.

Production of flour from whole wheat: Flour was also obtained from whole wheat grains by subjecting the grains to initial sorting, winnowing, washing in water to remove all adhering dirt, draining and drying in the cabinet dryer at 60^{o}C for 6 h. The dried grains were then milled into flour in a locally fabricated plate mill and then allowed to cool. The flour obtained was finally sieved using a sieve of 300-µm aperture and then kept in black polyethylene bag until needed for subsequent analysis.

2.3 Preparation of doughmeals from the flours of yam, green plantain and whole wheat grain

Doughmeal was respectively prepared from each of the flour source by reconstituting the flour in hot water (100^{o}C) at flour/water ratio of 1:4 (weight/volume). About 50% of the flour was added into the boiling water with vigorous stirring, using a wooden flat spoon, to form a non-smooth paste. The remaining quantity of the flour was then added gradually to this boiling, non-smooth paste with continuous stirring so as to facilitate non-formation of lumps and to ensure a homogenous gel formation. The smooth gel or thick paste eventually obtained is called doughmeal. The doughmeal obtained from yam, green plantain and whole wheat grains are therefore referred to as yam doughmeal, plantain doughmeal and wheat doughmeal respectively.

2.4 Determination of mean particle size (mps) of the flour

The particle size distribution of flour (250 g) from each botanical source was carried out using a sieve analysis technique with the aid of Endecotts Test Sieve Shaker (model 1 MK11-11381, London, UK). Sieves of different apertures (that is, 425, 300, 150 and 75µm) and pan were used by placing them in the shaker for 10 min. The flour retained on each sieve was weighed and the mean particle size (MPS) of the flour determined using the method of Arambula *et al.* (1998) as follows:

$$\text{Mean particle size (MPS)} = \frac{(W_1d_1+W_2d_2+\ldots.. +W_5d_5)}{R} \qquad \text{(eq. 1)}$$

where;
$W_{1\text{-}5}$ = weight of flour through each sieve
$d_{1\text{-}5}$ = size of mesh for each sieve
R = total recovery.

2.5 Determination of pasting properties of the flour

The pasting properties of flour from each of the botanical sources were determined using a Rapid Visco-Analyzer, RVA-Series 4 (Newport-Scientific, 1998). A sample of 4.0 g flour (14% moisture-basis) was transferred into a canister and approximately 25± 0.1 mL distilled water was added (correction factor was used to compensate for 14% moisture-basis). The slurry was heated to 50^{o}C and stirred at 160 rpm for 10 s for thorough dispersion. The slurry was held at 50°C for up to 1 min followed by heating to 95°C over about 7.3 min and held at 95°C for 5 min, and finally cooled to 50°C over about 7.7 min. The parameters calculated from the pasting curve include the pasting temperature, peak viscosity, time to peak, breakdown, holding strength or trough, setback, and final viscosity.

Evaluation of softness index of doughmeal

The softness index of doughmeal prepared from each of the botanical sources was determined using Precision Cone Penetrometer (Benchtop model, Pioden Controls Ltd., UK). Freshly prepared hot doughmeal was scooped inside a clean cylindrical tin container having only one end opened and a dimension of 6 cm (diameter) by 6 cm (height). After filling, the opened end was covered with an aluminium foil to prevent scale formation of the meal and the container was thereafter allowed to cool under ambient condition (29±2°C). After cooling, the doughmeal inside the container was subjected to penetrometer evaluation by positioning its centre perpendicularly to the falling probe of the penetrometer. The probe was finally released to fall freely from a standard distance to penetrate into the product in the cylindrical tin container. The total depth of penetration of the probe was then read on the penetrometer scale and the reading, expressed in millimetre (mm), was taken as an index of the food product's softness.

2.6 Evaluation of cohesiveness index of doughmeal

The rheological characteristics of doughmeal prepared from each of the botanical sources were evaluated using the Universal Testing Machine (model M500-50KN, Testometric, England). A determination procedure as described by Bolade (2009) was used for each sample. The doughmeal was initially prepared inside a cylindrical plastic container (with a diameter of 50 mm and 96 mm in height), the internal surface of which was first oiled with edible vegetable oil to facilitate easy removal after solidification. The hot doughmeal inside the cylindrical container was allowed to cool under ambient condition (29±2°C). After about 4 h it was removed from the container and the cylindrical doughmeal mould subjected to a compression test. The mould was placed between two parallel flat stainless steel circular plates each having a diameter of 100 mm. The machine was set at a speed of 20 mm/min and allowed to compress the cylindrical mould until the food sample began to rupture. The rheological variables of the doughmeal measured were the load at yield (N), deflection at yield (mm), strain at yield (%), load at peak (N), deflection at peak (mm), and strain at peak (%). The load at yield is essentially the force at which deflection or deformation increases without a corresponding change in force particularly just beyond the elastic limit of the food sample. The load at peak is the maximum or peak compressive force experienced by the food sample during a compression test. The deflection at yield is the point at which deflection increases without a corresponding change in the applied force. The deflection at peak is the deflection at maximum force. The percentage of such deflection/elongation is known as strain at peak (Testometric, 2007). The cohesiveness index of the food sample was equated to the strain at maximum load (%) which is the extent to which the cylindrical doughmeal mould could be deformed before it ruptured (Szczesniak, 1966; Pomeranz and Meloan, 1987).

i.e. Cohesiveness Index (Strain at Maximum Load)

$$= \frac{\text{Displacement or Deformation}}{\text{Original Height or Length}} \times 100$$

2.7 Determination of colour characteristics of doughmeal

The colour of doughmeal prepared from each of the botanical sources was evaluated by measuring L^* (brightness; 100 =white, 0 = black), a^* (+, red; -, green) and b^* (+, yellow; -, blue) parameters by means of a colour measuring instrument (ColorTec-PCM, model SN 3000421, USA). The L^* value is of most significant in this study while the brown index of the samples was calculated as (100 - L^*) (McGuire, 1992; Babajide *et al*., 2008).

2.8 Sensory quality rating of the doughmeal

Doughmeal samples obtained from the three botanical sources of yam, plantain and whole wheat respectively were subjected to sensory evaluation using a scoring test. A 50-member, semi-trained panel was requested to carry out the rating of the doughmeal samples. The panelists were all familiar with the food products while they were also instructed on the use of sensory evaluation procedures. Each of the panelists was asked to rate the samples on the basis of colour, taste, aroma, texture (mouldability) and overall acceptability using a nine-point hedonic scale (i.e. 9= like extremely; 5= neither like nor dislike; 1= dislike extremely) (IFT 1981; Lawless and Heymann, 2010).

2.9 Statistical analyses

All determinations reported in this study were carried out in triplicates. In each case, a mean value and standard deviation were calculated. Analysis of variance (ANOVA) was also performed and separation of the mean values was by Duncan's New Multiple Range (DNMR) Test at $p<0.05$ using Statistical Package for Social Scientists (SPSS) software, version 16.0.

3. Results and Discussion

3.1 Mean particle size and pasting characteristics of flours used in doughmeal preparation

Figure 1 shows the mean particle size of flours from yam, plantain and whole wheat used in doughmeal preparation. The mean particle size of the flours ranged between 120 and 136 µm with whole wheat having the lowest value while plantain had the highest with significant differences ($p<0.05$). The lowest mean particle size of whole wheat flour may be attributed to the relative weak associative forces binding the endosperm together thereby giving rise to smaller-sized particles during milling. The mean particle size of flours generally plays an important role in its influence on the textural characteristics of food products derived from such flours (Hebrard *et al*., 2003).

The pasting properties of flours from yam, plantain and whole wheat meant for doughmeal preparation is shown in Table 1. The pasting temperature of whole wheat flour was the lowest (78.1^{o}C) while that of yam flour was the highest (79.1^{o}C) but with no significant difference at $p<0.05$. Lower pasting temperature implies faster gelatinization of the starch granules during heating. The peak viscosity of the flours ranged between 224.1 and 252.4 RVU with yam and whole wheat flours having the lowest and highest values respectively with significant differences ($p<0.05$). The peak viscosity is an index reflecting different rates of water absorption and swelling of starch granules of these flours during heating (Ragaee and Abdel-Aal, 2006). The breakdown viscosity of plantain flour was the lowest (28.3 RVU) while that of yam flour was the highest (46.8 RVU) with significant differences ($p<0.05$). Lower breakdown viscosity implies greater paste stability or minimal starch granule disintegration during heating and shear force application (Dengate, 1984; Farhat *et al*., 1999).

The final viscosities of the flours ranged between 288.7 and 312.5 RVU with whole wheat and plantain flours giving the lowest and highest values respectively with significant differences ($p<0.05$). Lower final viscosity implies minimal aggregation of the amylose molecules in the paste (Miles *et al*., 1985). The setback viscosity (version II) of the flour samples ranged between 36.3 and 83.4 RVU with whole wheat and plantain flours giving the lowest and highest values respectively with significant differences ($p<0.05$). The setback viscosity (version II) is a parameter that can be used for predicting the textural characteristics of food products prepared from the flours (Newport-Scientific, 1998). Lower setback viscosity (version II) therefore implies a probable higher product cohesiveness that those with higher values.

3.2 Softness index of doughmeals prepared from the reconstituted individual flour of yam, plantain and whole wheat

Figure 2 shows the softness index of doughmeal obtained from different botanical sources. The softness index of doughmeal from yam, plantain and whole wheat were 21.8, 25.3 and 27 mm respectively. The implication of this observation is that doughmeal from whole wheat had the highest degree of softness while yam doughmeal had the least. The proportion of the chemical constituents of each category of flour and the degree of their interactions during preparation might have played a major role in the softness index of the food product. It had earlier been observed that the rheological properties of a food product are greatly governed by the concentration of chemical constituents of such product (Gupta *et al*., 2007). The softness index can be regarded as a parameter that simulates the force required to compress the food product between the tongue and palate during consumption thereby relaying a sensory feeling as to whether the food product will eventually be chewed or swallowed. The chewability or swallowability of a food product already in the mouth is usually determined by the prevailing textural characteristics of such food product (Prinz and Lucas, 1995; Szczesniak, 2002). The relative high softness index of doughmeal from whole wheat can therefore predispose it towards easier swallowability than others.

3.3 Cohesiveness index of doughmeals prepared from the reconstituted individual flour of yam, plantain and whole wheat

The compression test characteristics of doughmeal prepared from flours of yam, plantain and whole wheat respectively are presented in Table 2. The load at yield ranged between 11.9 and 12.4 N with no significant differences at $p<0.05$. The load at yield is regarded as the force at which deformation increases without a corresponding change in force particularly just beyond the elastic limit of the food sample (Testometric, 2007). The load at peak for the doughmeal samples ranged between 31.3 and 37.3 N with whole wheat and plantain doughmeals giving the lowest and highest values respectively with significant differences ($p<0.05$). The load at peak is regarded as the maximum compressive force experienced by the food sample during a compression test. The implication of this observation is that a lower force will be required to hand-mould whole wheat doughmeal during consumption when compared to others. Hand-mouldability of the food bolus is a major preliminary step taken by doughmeal consumers before the bolus is eventually swallowed together with a vegetable soup or stew. When the load at yield or peak is divided by the original cross-sectional area of the food sample, the resultant quantity is known as stress at yield or peak respectively. The deflection at yield for doughmeal samples ranged between 3.9 and 4.2 mm with no significant differences ($p<0.05$) while that at peak ranged between 16.5 and 21.4 mm with significant differences ($p<0.05$). The percentage of deflection at yield or peak is known as strain at yield or peak respectively.

The strain at peak for doughmeal samples, taken as the cohesiveness index of the food product, was observed to range between 15.4 (plantain) and 19.4% (whole wheat). This observation is suggesting that doughmeal from the whole wheat has a higher tendency of being cohesive than others. Higher cohesiveness of food product like doughmeal usually leads to a better hand-mouldability of its food bolus thereby influencing greater consumers' satisfaction and acceptability.

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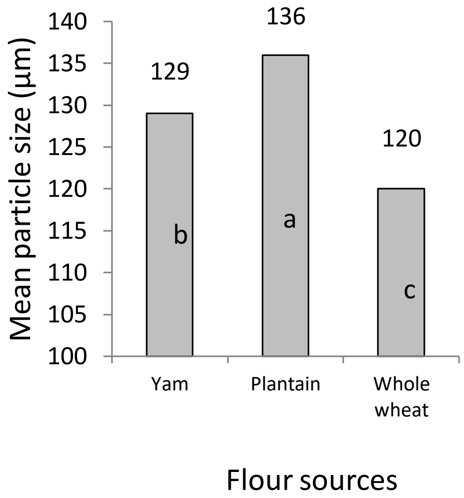

Fig 1: Mean particle size of flour meant for doughmeal preparation.
Bars carrying the same letters are not significantly different at p<0.05.

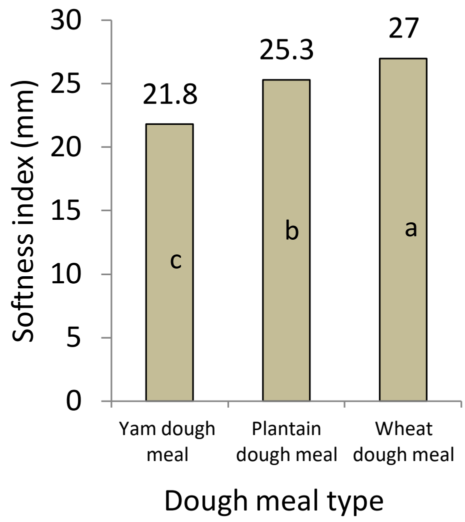

Fig 2: Softness index of dough meal prepared from flours of different botanical sources.
Bars carrying the same letters are not significantly different at p<0.05.

Table 1: Pasting properties of flours from yam, plantain and whole wheat meant for doughmeal preparation.

Flour source	Pasting factor[1]							
	Pasting temperature (^oC)	Peak viscosity (RVU)[2]	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback-I (Difference between final viscosity and trough; RVU)	Setback-II (Difference between final and peak viscosity; RVU)	Time to reach peak viscosity (min)
Yam	79.1^a	224.1^b	177.3^c	46.8^a	298.3^{ab}	121.0^a	74.2^a	5.5^a
Plantain	78.8^a	229.1^b	200.8^b	28.3^c	312.5^a	111.7^a	83.4^a	5.2^a
Whole wheat	78.1^a	252.4^a	216.1^a	36.3^b	288.7^c	72.6^b	36.3^b	5.6^a

[1]Results are mean values of triplicate determinations. Mean values followed by different superscripts in each column are significantly different at p<0.05.
[2]RVU = Rapid Visco Unit.

Table 2. Compression test characteristics of dough meal prepared from yam, plantain and whole wheat flours respectively.

Source of dough meal	Compression variable[1]							
	Load at Yield (N)	Stress at Yield ($x10^{-3}$ N/mm^2)	Load at Peak (N)	Stress at Peak ($x10^{-3}$ N/mm^2)	Deflection at Yield (mm)	Strain at Yield (%)	Deflection at Peak (mm)	Strain at Peak (%)
Yam	12.2^a	4.0^a	36.5^a	12.1^a	4.2^a	3.8^a	18.8^b	17.1^b
Plantain	12.4^a	4.1^a	37.3^a	12.4^a	3.9^a	3.6^a	16.5^c	15.4^b
Whole wheat	11.9^a	3.9^a	31.3^b	10.4^a	4.2^a	3.8^a	21.4^a	19.4^a

[1]Mean values followed by different superscripts in the column are significantly different at p<0.05

3.4 Colour characteristics of doughmeals prepared from the reconstituted individual flour of yam, plantain and whole wheat

The colour characteristics of doughmeal obtained from flours of yam, plantain and whole wheat respectively are presented in Figure 3. The brown index of doughmeal from yam, plantain and whole wheat were 45.8, 46.3 and 42.2 respectively. The implication of this observation is that plantain doughmeal is the most brownish which might be due to partial enzymatic browning in the plantain slices during drying (Tortoe *et al.*, 2009) and non-enzymatic browning in the flour. It had earlier been observed that plantain flour could

Table 3: Sensory quality rating of dough meal prepared from yam, plantain and whole wheat flours respectively.

Source of dough meal	Sensory factor[1]				
	Colour	Taste	Aroma	Texture (mouldability)	Overall acceptability
Yam	8.2[a]	7.2[a]	6.9[b]	7.9[a]	8.1[a]
Plantain	7.2[b]	6.9[a]	7.8[a]	6.5[b]	6.9[b]
Whole wheat	5.6[c]	5.3[b]	6.6[b]	5.1[c]	5.5[c]

[1]Results are mean values of 50-member sensory evaluators. Mean values followed by different superscripts in each column are significantly different at p<0.05

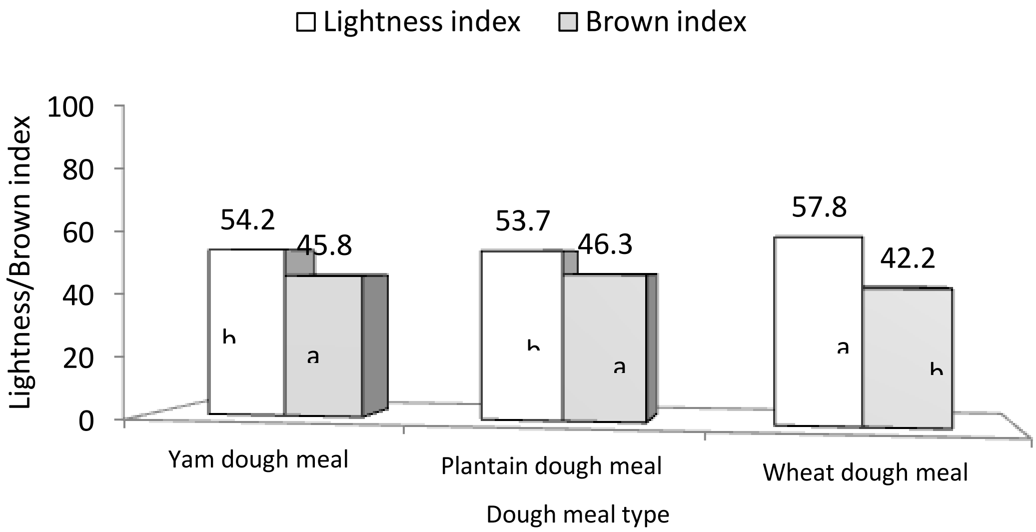

Figure 3: Colour characteristics of dough meal prepared from flours of different botanical sources. Bars carrying the same letters are not significantly different at p<0.05

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undergo non-enzymatic browning during storage thereby causing degradation of its colour (Wiley, 1994; Ahvenainen, 1996). The brown colour formation in the doughmeal generally in the course of its preparation can be attributed to a combined interaction of water, flour and thermal energy which usually leads to colour formation via non-enzymatic browning. Colour plays an important role in the acceptability of doughmeal (Mestres *et al*., 2004) as products with darker colour are traditionally rejected.

3.5 Sensory quality rating of the doughmeals prepared from the reconstituted individual flour of yam, plantain and whole wheat

The sensory quality assessment of doughmeals obtained from different botanical sources is presented in Table 3. Yam doughmeal was generally rated the highest in terms of colour, taste, texture (mouldability) and overall acceptability while plantain doughmeal was rated the highest only in terms of aroma. Doughmeal from whole wheat was generally rated the lowest in terms of the entire sensory variables. The explanation for this observation may be that the consumers are traditionally used to yam doughmeal and so doughmeal from any other botanical source may not be readily acceptable to them even if it possesses the desirable quality attributes. Essentially, it is a reflection of consumers' preference for traditionally-based food product rather than newly-introduced, exotically-related ones. It had earlier been observed that food selection by consumers is generally governed by cultural preferences (beliefs, sensory attributes, social and personal elements), affordability (expendable income, food price, time and personal energy), education and media (Hernandez *et al*., 1974; Jerome *et al.*, 1980; Johns and Kuhnlein, 1990; Murcott, 1992).

4. Conclusion

It may be concluded that in the preparation and consumption of doughmeal from diverse flour sources in Nigeria, greater preference is still for yam doughmeal in spite of the fact that others compared favourably with it in terms of certain objective variables such as low setback viscosity (an indicator for reduced retrogradation tendency and better textural characteristics), low brown index (indicator for non-dark colour) and relative high value of strain at peak (cohesiveness index). Cultural preference was also suspected to have played a major role in the acceptability of yam doughmeal over others by the consumers.

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